(Page 188.) The interference of a current flowing from east to west with another which is flowing from southwest to northeast must necessarily generate a rotatory motion in the direction opposite to that of the hands of a watch. According to this view the hurricane which advances from southeast to northwest in the under trade-wind represents the advancing point of contact of two currents in the upper strata which are moving in directions at right angles to each other. This is the primary cause of the rotatory motion.

(Page 196.) The upper part of the cyclone will accordingly dilate at once and advance in a direction different from that of the other part. Hence, as a secondary phenomenon, a suction will ensue in the center of the cyclone and, also, a diminution of pressure over the surface of the earth.

In regard to the general circulation, Dove conceives the vertical section as a figure ∞, with the ascending currents *both at the equator and poles,* crossing in the outer limit of the Tropics.

(Page 271.) The upper counter-trade of the Torrid Zone descends at the outer edge of this area; flows into the Temperate Zone; rises again when it comes into higher latitudes; flows back as a polar current in the upper strata of the atmosphere of the Temperate Zone; descends afresh at the Tropics; flows in toward the equator along the surface of the ground as the ordinary direct trade-wind, and at the equator rises again.

(Page 221.) The West India hurricanes are due to the interference of lateral cross-currents with the upper trade-wind on its return from the equator, portions of which, being forced to enter the lower strata of the atmosphere, meet with a constant wind, moving in a direction opposite to their own and thus produce a cyclone. Outside the trade-wind area the upper current descends to the surface of the earth, and is predominant there in different districts at different times, while the under-current in the opposite direction is not constant. Here, then, we shall find that the conditions of interference will be constantly presented, but the currents will be directly opposed to each other so that they will only check each other's progress.

It is evident that Dove's theory of interference and obstruction for the formation of cyclones induced him to describe a circulation over the hemisphere which is partially correct in the temperate zones, but erroneous in the polar zones. Since the ordinary canal theory of the circulation with a poleward current from the equator to the pole in the upper strata, and a return current from the pole to the equator in the lower levels (Ferrel, Oberbeck), could produce no currents of different temperatures on the same levels, whether high or low, therefore in the Cloud Report I described the "leakage current," escaping from the Tropics in certain longitudes, as on the western side of the Atlantic high area, by which warm currents are thrown into the United States from the south to meet the cold currents from the north in the lower strata. The theory of interference and obstruction was rejected, and a theory of the asymmetric cyclone and anticyclone described, depending on the lateral interpenetration of the warm and cold masses, thus using the key which Dove threw away, and which is evidently the only key to unlock this problem. Compare Cloud Report, Charts 20–35, p. 606–609, 612, 615–633, and numerous papers in the MONTHLY WEATHER REVIEW.

Ferrel sought the explanation for cyclones in a cold- or warm-centered vortex, as did Guldberg and Mohn, Oberbeck, and others, using different solutions of the second equation of motion, but the source of heat energy at the center is so inconsistent with the observed distribution of the temperature, that the symmetrical cyclone was abandoned by me in favor of the asymmetrical cyclone and anticyclone. The difficulty in making progress with this view was due to the fact that for several years following 1898 reliable temperature observations in the *free* upper strata were not available as they have since become thru the reports of balloon and kite ascensions. Those that have been obtained show that the asymmetric temperature distribution found at the surface presists to the top of the cyclonic disturbance of the eastward drift in substantially the same relations, so that the problem can now be resumed. The preceding papers of this series, as well as the "Studies on the Thermodynamics of the Atmosphere," 1907, are simply introductory to the cyclonic problem, which will no doubt require much careful mathematical study.

It is easy to state a theory in general terms of the action of warm and cold masses on each other in horizontal directions, but to pass thru the thermodynamic equations to the dynamic stream-lines in so complex a system of flow, involving hydrodynamic conditions which are neither simple nor constant, is a work of extreme difficulty. Hann found evidences that the temperatures in the levels above the surface layers did not conform to the central or symmetrical theory of Ferrel, but he believed that the change of temperature, from warm to cold in cyclones, for example, was a dynamic effect such as is produced in ascending currents. The asymmetric theory calls for no such dynamic action to produce thermal effects, but, on the contrary, it takes the observed existing thermal conditions, and finds from them the necessary cyclonic dynamic circulations. In the preceding papers of this series we have been able to trace certain tornadoes and the hurricane to the simple dumb-bell vortex, but in the ocean-cyclone there is evidence that the vortex is becoming very imperfect, so that the dumb-bell vortex must be greatly modified to be applicable to the ocean-cyclone, and so much the more, to the land-cyclone. One of the chief labors of the Cloud Report, 1896–97, was to compute the radial component of the velocity, u_2, from the cloud observations, and this result, Table 126, p. 626 of that report, will be employed in the following paper on the land cyclones to bring out some of the leading features of this difficult problem.

DEFICIENT HUMIDITY INDOORS.

By F. H. DAY, B. Sc., Demonstrator of Physics, McGill University.
Dated Montreal, December 21, 1908.

In view of the republication[1] of Prof. R. DeC. Ward's observations on the relative indoor and outdoor hygrometric conditions in the neighborhood of Boston and Cambridge, Mass., it is interesting to compare these with some similar investigations carried on in Montreal during the winters of 1906 and 1908 by Dr. T. A. Starkey and Dr. H. T. Barnes,[2] of McGill University. This work was undertaken in order to determine the effect of a successively dry atmosphere on the human organism—a question of great moment in Canada, especially in those parts where during the winter months the heating of the houses necessitates the heating of the indoor atmosphere, thereby causing a tremendous drying of the air. And this is the first condition for the difference between the air in the two places. Professor Ward was working with an indoor and outdoor difference of about 35° F., while in Montreal this increases to a difference of from 70° to 100° F. during the colder months. Knowing that if we warm a given quantity of air completely saturated with water vapor at the initial temperature, it no longer remains saturated, we can readily see what an enormous change in the relative humidity is entailed by heating outside air at a temperature of 0° F., or below, to a higher temperature.

As a danger to the health caused by this excessive dryness, Professor Ward mentions the strain put upon the body going out from a high temperature and very dry atmosphere into an atmosphere low in temperature and comparatively high in humidity. Starkey and Barnes find another and quite as serious a danger in the direct effect of the dry atmosphere itself. This condition is well borne out by some striking illustrations. To quote from this paper:[2]

The action of a dry atmosphere affects primarily the mucous membranes lining the respiratory tract, chiefly that of the nose, the throat, and the bronchial tubes. It is a peculiarly mechanical irritant, resulting in a condition of congestion of the mucous membranes before mentioned. If this irritation be continued for any length of time these swollen membranes with difficulty regain their normal state. We have thus all the conditions favorable for a chronic catarrh, and this chronic condition being established we get all the typical symptoms of nasal-pharyngeal

[1] Monthly Weather Review, September, 1908, 36:281.

[2] Trans. Roy. Soc. Can.

catarrh, spreading often to the eustachian tubes communicating with the little ear. When considering the effect of an irritation due to dry air on a mucous membrane already irritated or congested by some disease, e. g., tuberculosis, bronchitis, pneumonia, etc., none can deny for a moment the deleterious results that necessarily follow such an added irritation. Or, if the lungs are normal and healthy and the mucous membrane lining them gets in an irritated state, the conditions are then favorable for the grafting on of some disease, e. g., most marked of all, tuberculosis. If other mechanical irritants besides that produced by dry air can be the starting point of predisposition of such a disease, why not that produced by dry air?[3]

The following are two of the cases recited:

Case 1.—A. B. arrived in Canada late in the year, and during the winter suffered greatly from congestion of the throat and nose and to a less extent of the bronchial passages. The air of the room which he occupied was suspected, but chemical analysis showed its composition to be fairly good, CO_2 was 0.08 per cent. The air in the room where he spent most of the day showed CO_2=0.07 per cent, but the symptoms of congestion never developed there, consequently vitiation by excess of CO_2 could not account for the trouble. On testing the relative humidity it was found to be from 40 to 50 per cent. The symptoms of congestion always disappeared rapidly when the individual went out of doors. Keeping the windows open regularly prevented the congestion.

Case 2.—The case of a family in which there were five children, three boys and two girls, ranging from three to ten years. They had returned to town, after a stay in the country during the summer. The boys quickly began to lose tone as the winter came on. They all exhibited congestion of the nose and throat of a chronic nature. The two little girls continued well. It was found that the girls slept in a room where the windows were kept open night and day, but not so the boys. Chemical examination in the different rooms showed no material increase of the CO_2 or the presence of other deleterious constituents. The relative humidity was 40 per cent. In the boys' room a minimum of 38 per cent was obtained.[4] In the girls' room the relative humidity averaged from 50 to 55 per cent. Fresh air was admitted by open windows to the boys' room and they showed signs of improvement immediately, and are now quite well.

From the evidence of throat and nose specialists in Montreal there would seem to be little doubt as to the deleterious action of a dry atmosphere upon the human body,

In Table 1 we have a comparison of the indoor and outdoor relative humidities, with the temperatures for the colder months:

TABLE 1.—*Average winter temperatures and humidities, indoors and outdoors, at Montreal, Canada.*

	October.	November.	December.	January.	February.	March.
Average relative humidity, outdoors	87.8	86.7	79.2	78.1	79.2	80.3
Average temperature, indoors, in degrees F.	64.0	64.0	65.0	66.0	66.0	65.0
Average relative humidity, indoors, windows closed	58.0	53.0	46.0	41.0	42.0	45.0
Average relative humidity, indoors, windows open	66.0	61.0	58.0	57.0	57.0	58.0

These results agree in differences very well with those obtained by Professor Ward. But the indoor percentages are much higher than one would expect, considering the range of temperature. As is shown later in this paper, this is undoubtedly due to the type of instrument used to measure the humidity. The stationary form of wet-bulb and dry-bulb hygrometer was used, and comparisons with the Regnault and the chemical method showed the instrument to be wholly inadequate for the lower readings. As an illustration of this, in one of Starkey and Barnes' observations the Regnault hygrometer gave a dew-point of 3.75° F. for the air in the laboratory during a a cold winter's day. The relative humidity, calculated from this dew-point, is 6.25 per cent. But the indications of the wet-and-dry hygrometer of the stationary type were interesting. The dry-bulb registered 69° F., and the wet-bulb 57° F., showing a difference of 12°. This gives a relative humidity of 45 per cent.

A comparison was made with a chemical hygrometer, and the following results obtained:

TABLE 2.—*Simultaneous determinations of relative humidities by two methods.*

Serial number.	Stationary wet and dry-bulb.	Chemical analysis.
	%	%
1	78.0	70.5
2	71.0	71.0
3	53.4	34.7
4	55.1	35.0
5	52.2	36.5
6	52.2	36.5
7	54.0	36.0
8	53.0	28.5
9	38.8	30.5
10	39.0	29.0

Following is the discussion of the table:

The first six observations were taken on different days at very irregular intervals, extending over six weeks in the spring of 1906. The wet- and dry-bulb thermometers were suspended in the middle of the laboratory, where only a slight current of air was obtained. The disparity in the results here is extremely striking, and from the figures obtained one can not deduce any correction applicable to the wet- and dry-bulb instrument. Where the humidity is about 70 to 80 per cent the results apparently are not very far from the average condition of the humidity, but with a fairly still atmosphere and a very low percentage of moisture the results vary tremendously.

The last four observations, namely, Nos. 7, 8, 9, and 10, are interesting, being all taken on the same day, 7 and 8 being taken in the morning at a two-hour interval, the wet- and dry-bulb instruments being placed under still air conditions as above mentioned. Here the discrepancy is about 20 per cent. In Nos. 9 and 10 observations were taken in a very marked draft of air, the instruments being placed in the drafts from three large, open windows, and one would not be very far short of the mark by saying that the conditions were almost identical with those in the open. The evaporation from the wet-bulb had thus free play and would be practically at its maximum.

The relative humidities under these conditions correspond fairly closely with those obtained by exact chemical analysis. It is, of course, as one would expect, that when full play is given to the evaporation the record ought to be nearer the truth than when the instrument is placed in a still atmosphere and the rate of evaporation is interfered with to a large extent. But one can easily see from the last set of observations that no figures of correction are possible, because the rate of evaporation depending so exactly upon the movement of the air, any interference with the latter would necessarily throw the results out a great way from the truth.

The instrument used in this case, as is observed in a succeeding paper by the same authors,[5] had a rather small spherical bulb and a comparatively long wick. Comparisons were made of different forms of the stationary wet-and-dry instruments by altering the size of the thermometer bulbs, using different kinds of wicks, changing the position of the reservoir, varying the temperature of the feed water, and using air currents of different velocities. The effect of an air current is readily shown by the following results, where two instruments are used, one with a large bulb and one with a small:

Instrument No. 1: difference in temperature between bulbs before supplying air currents, 14.9° F.; difference in temperature between bulbs after supplying air currents, 18.8° F.

Instrument No. 2: difference in temperature between bulbs before supplying air currents, 16.2° F.; difference in temperature between bulbs after supplying air currents, 20.5° F.

These observations were taken on a day when the Regnault dew-point hygrometer gave a relative humidity of a little over 6 per cent. No. 2 in the last reading gives approximately this same value. At the same time it was established that it makes little difference whether the rate of air current be fast or slow, provided that there is a perceptible rate.

A sling-psychrometer was obtained and its readings compared with the Regnault. The type of instrument was such that it was necessary to bind a moist wick above the bulb as

[3] By "dry air" is here meant air artificially dried. The benefit of a dry climate to patients suffering from tuberculosis is well known. We know of no evidence to show that the same benefit or any is derived from artificially dried air.

[4] These measurements were made with a stationary type of wet- and dry-bulb hygrometer. Later measurements indicate that such instruments give far too high values of the humidity for a dry atmosphere.

[5] Trans. Roy. Soc. Can.

a reservoir, to prevent the bulb drying before the minimum reading was obtained. This was undoubtedly due to the spherical form of the bulb, causing it to be very insensitive. Also the reservoir had to be protected by tin-foil, in order to prevent a too great lowering of the temperature of the feed water, due to excessive evaporation. Fairly constant readings were obtained.

TABLE 3.—*Comparisons of Regnault's and the sling psychrometer.*

Type of instrument.	Date.	Temperature.			Relative humidity.	Dew-point.
		Outdoor.		Indoor.	Indoor.	Indoor.
		Max.	Min.			
		° F.	° F.	° F.	%	° F.
Sling	Feb. 4, 1908	—3.5	—20.0	64.9	4.5	
Regnault	Feb. 4, 1908	—3.5	—20.0	66.2	5.2	—2.0
Sling	Feb. 5, 1908	—6.4	—20.6	62.6	2.8	
Regnault	Feb. 5, 1908	—6.4	—20.6	63.1	5.1	—5.0
Sling	Feb. 8, 1908	2.0	—8.0	68.0	5.8	
Regnault	Feb. 8, 1908	2.0	—8.0	69.0	5.5	—1.0
Sling	Feb. 11, 1908	30.0	15.8	68.5	10.7	
Regnault	Feb. 11, 1908	30.0	15.8	66.2	5.2	—2.0
Sling	Feb. 14, 1908	39.8	34.2	73.8	24.4	
Regnault	Feb. 14, 1908	39.8	34.2	73.5	21.9	—32.1
Sling	Feb. 15, 1908	35.0	29.5	71.2	26.0	
Regnault	Feb. 15, 1908	35.0	29.5	71.2	25.2	—34.0

The first two sets of observations were made without the tin-foil protection over the wick, the last four with it. The water feeding down was in the first case cooled before coming into the bulb and this gave too low indications.

The effect of the low outside temperature is well shown in the excessively low humidity inside. It was noticed also that in some cases hoar frost was deposited on the Regnault instrument instead of dew. Speaking of this, Doctors Starkey and Barnes remark—

> An interesting question arises here as to the deposition of moisture in the form of vapour or hoarfrost. The vapour pressure of hoarfrost is considerably smaller than that for supercooled [subcooled] water, giving results 25 per cent too high at 0° Fahrenheit. We think there is no question that for very low temperatures of the dew-point we got in all cases hoarfrost.

In all these observations Glaisher's tables were used, with extrapolations for the lower values. During the autumn of the present year the writer, using the type of psychrometer[6] employed by the United States Meteorological Department [the Weather Bureau] and the tables accompanying it, made some comparisons with the chemical hygrometer, obtaining very good results, even at the lower values.

TABLE 4.—*Comparisons of methods.*

Date.	Chemical hygrometer	Sling psychrometer.	Stationary psychrometer.
1908.	%	%	%
November 10	49.9	48.0	58.0
November 14	34.0	34.0	48.0
November 21	32.0	24.0	34.0
November 24	41.6	42.2	47.0
December 2	25.3	26.0	37.0
December 4	20.7	20.0	32.5

The agreement here [between the chemical method and the Weather Bureau method] is as close as could be expected. At least, there is no marked departure from the chemical readings at the lower humidities. The stationary psychrometer is seen to depart very considerably as the humidity falls.

Professor Ward, in his paper, suggests the placing of water pans either over the furnaces for hot air heating or over the steam coils in steam-heated houses. Doctors Starkey and Barnes considered this matter in concluding their paper.

> Methods have been devised for supplying moisture to the air of houses, but a few figures to show the amount of moisture required to bring the air up to a normal healthy condition will be fourd to be somewhat discouraging (as far as the efficacy of pans go). Thus in an ordinary sized dwelling house, when due allowance is made for the amount of air required by each person per day, something like 33 gallons of water must be evaporated daily to keep the air at a relative humidity of 75 per cent. Other difficulties arise when this is accomplished. Condensation takes place on the windows when the air temperature outside is very low. Experience has shown that this commences at a humidity of about 40 per cent. We are inclined to think that much could be accomplished by maintaining the humidity, even at this latter figure, and that the question should be earnestly considered in order to improve the general health of the large proportion of the people who spend the greater part of their lives in artificially heated buildings.

Some later measurements by Starkey and Barnes during the coldest weather in the winter of 1907–8 showed a relative humidity of only 3.5 per cent in one of the university buildings. That this is attained also in private dwellings and schools generally seems likely, unless some means are taken to introduce moisture. The want of attention to this fact is responsible, no doubt, for much headache and general lowering of the vitality of scholars and others in the winter time who have to spend this time indoors. A steam jet seems to be about the only way of correcting for the deficient humidity during the coldest weather. Pans placed about a house are but as a drop in a bucket and have but little influence. Steam humidifiers are now available in Montreal for private houses employing the hot water system of heating, which system offers the most difficulty to obtain adequate moisture. Wherever these have been installed great benefit has resulted in general health. An actual saving of fuel also results from the lower temperature necessary in order to maintain a comfortable living room.

NOTE BY THE EDITOR.

One comment on this instructive article on humidity indoors comes naturally to the minds of those who have worked for many years on the problem of determining the humidity of our atmosphere, viz, that the use of the wet-bulb in still air has long since been abandoned by meteorologists in Germany and America, altho it continues to be used in countless private and public buildings. The whirled psychrometer was introduced by Arago about 1830, and the ventilated psychrometer by Belli in the same year; the equivalent sling psychrometer had been used by Saussure in 1786, and by Espy from 1829 onward. The complete theory, the formulas, and tables for the use of the cylindrical wet-bulb with a specific rate of ventilation (6 meters per second) was prepared by Ferrel[7] in 1885. Equivalent formulas and tables have also been prepared by Grassmann, Ekholm, and others. The instrument, its method of use, and the tables for reduction must all be adapted to each other. It is improper to use Glaisher's tables in reducing the readings of the ventilated psychrometer or Ferrel's tables in reducing the still psychrometer. The formula for the cylindrical bulb necessarily differs from that of the spherical bulb, on account of diffusion, radiation and ventilation, rather than on account of sensitiveness, since we only read when the temperature has become stationary. Assmann's ventilated psychrometer is the most convenient for station work, but more expensive and less portable than the sling psychrometer; but these and Arago's whirled apparatus all agree most closely with the dew-point and the chemical methods when the observations are carefully executed.

The tables of vapor pressure, at and below freezing, differ according as the evaporating surface is solid ice or subcooled water.[8] Generally, the table for ice must be used, but not necessarily always.—*C. A.*

[6] This type of sling hygrometer has thermometers with long cylindrical bulbs. These are more sensitive than the bulbs on the sling used by Starkey and Barnes, on account of having a greater surface to the volume of mercury enclosed.

[7] See Ann. Rep. Chief Signal Officer, 1886, p. 232–259.

[8] See Smithsonian meteorological tables, Washington, 1907.